4.8 Ground-Water Protection and Monitoring Program

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The strategy for protecting ground water at the Hanford Site is presented in the *Hanford Site Ground Water Protection Management Plan* (DOE 1995d). Two of the key elements of this strategy are to 1) protect the unconfined aquifer from further contamination, and 2) conduct a monitoring program to provide an early warning when contamination of ground water does occur. These elements are reaffirmed by the recommendations of the Hanford Future Site Uses Working Group to "protect the Columbia River from contamination" and to "deal realistically and forcefully with ground-water contamination" (Drummond et al. 1992). The ground-water monitoring program at the Hanford Site monitor and document ground-water quality to effectively meet the needs of these elements. The monitoring programs are designed to document the distribution and movement of ground-water contamination and to assess the movement of contamination into previously uncontaminated areas. Monitoring provides the historical baseline for evaluating current and future risk from exposure to ground-water contamination and for deciding on remedial options. The geology and hydrology of the Hanford Site are the major controls on the movement of contaminants in ground water so hydrogeologic studies are integrated into the monitoring program.

The effort to protect ground-water quality at the Hanford Site is being implemented through programs to minimize wastes being discharged to the soil column and through site remediation activities being carried out in accordance with the Tri-Party Agreement, which provides a framework for remediation of the Hanford Site over a 40-year period. A summary of accomplishments in waste minimization and Site remediation is presented in Section 2.0, "Environmental Compliance Summary."

The DOE has prepared a *Plan and Schedule to Discontinue Disposal of Liquids Into the Soil Column at the Hanford Site* (DOE 1987), which presents a plan for providing alternative treatment and disposal of contaminated effluent discharged to the soil. Of the 33 major waste streams identified, the Phase I (higher priority) streams have either been eliminated or are being treated before diverting them to a treated effluent disposal facility, which is located east of the 200-East Area. In addition, process condensate from the 242-A Evaporator is discharged to a state-approved facility (C-018H) north of the 200-West Area after treatment at the 200 Area Effluent Treatment Facility. These facilities are discussed in detail in Section 2.3, "Current Issues and Actions." Significant reductions in disposal of liquids to soil have occurred recently. For example, in 1987 over 23 billion L (6 billion gal) of liquid effluents were discharged to the soil column. Less than 11 billion L (3 billion gal) were discharged annually as of 1993. This was reduced to approximately 4.9 billion L (1.3 billion gal) in 1995. The rate was approximately 25 L/s (400 gal/min) by late 1995 (DOE 1995d), which equates to an annual volume of approximately 790 million L (210 million gal). The locations and status of Phase I streams are shown in Figure 4.8.1. Ground water is pumped for drinking water and other uses at a few locations on the Hanford Site. Drinking water supplies are monitored at the point of use by ICF Kaiser Hanford Company and Pacific Northwest National Laboratory. Results of the radiological monitoring conducted by Pacific Northwest National Laboratory are summarized in Section 4.3, "Hanford Site Drinking Water Surveillance." Water samples are collected directly from water supply wells by the Ground-Water Surveillance Project. The locations of wells completed in the unconfined aquifer that are used for water supplies are shown in Figure 4.8.2.

Hydrogeology

The Hanford Site lies within the Pasco Basin, one of several structural basins within the Columbia Plateau. Principal geologic units beneath the Hanford Site include, in ascending order, the Columbia River Basalt Group, the Ringold Formation, and the Hanford formation (Figure 4.8.3).

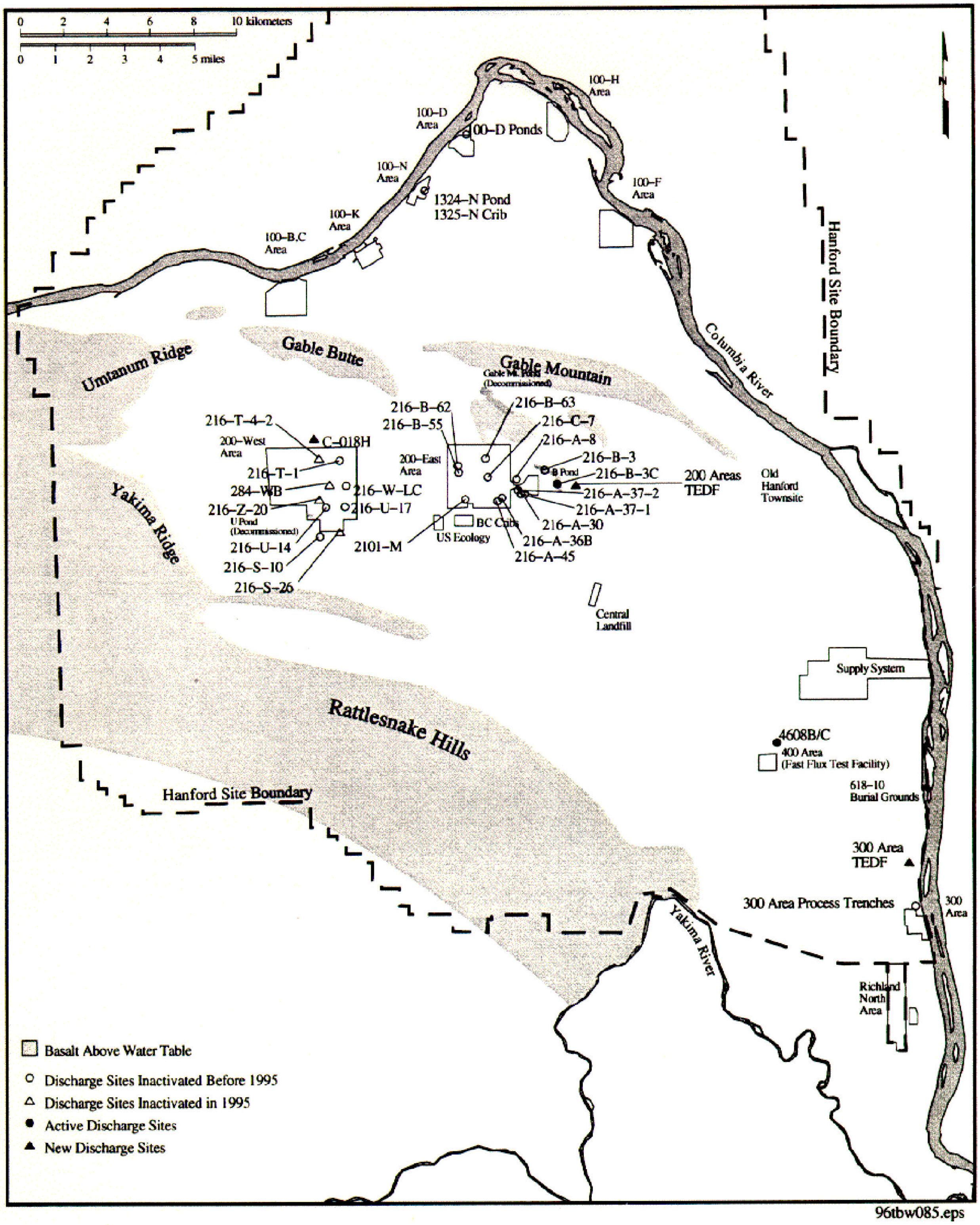

Figure 4.8.1. Disposal Facilities for the Major Liquid Waste Streams at the Hanford Site

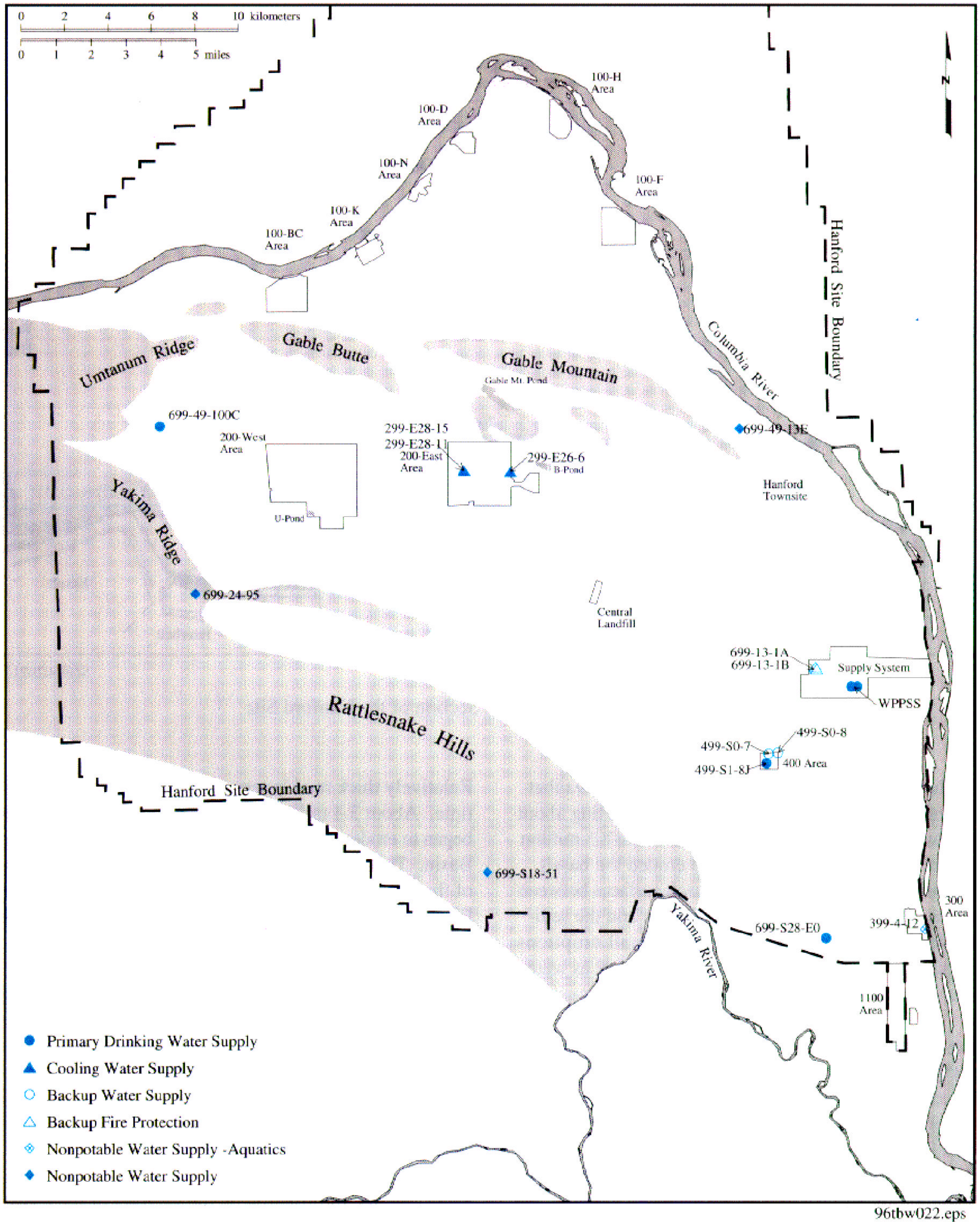

Figure 4.8.2. Water Supply Wells in the Unconfined Aquifer at the Hanford Site

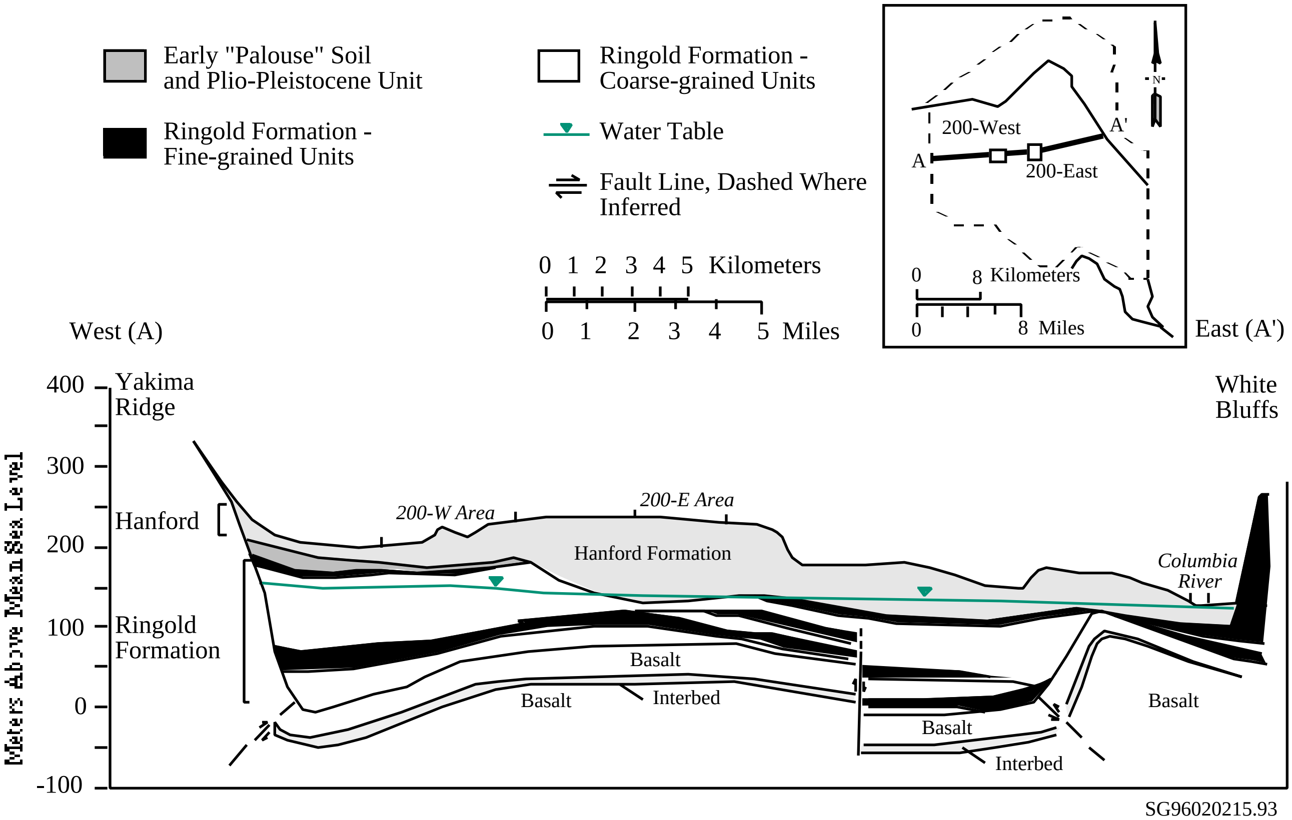

Figure 4.8.3. Geologic Cross Section of the Hanford Site

The Columbia River basalts were formed from lava that periodically erupted from volcanic fissures starting about 17 million years ago and continuing until about 8.5 million years ago. The regional river system eroded the basalt and deposited sediments across the basalt surfaces between eruptions. Zones between the basalt flows and the sediments deposited as interbeds between basalt eruptions are frequently water-bearing zones that are used as water sources in areas around the Hanford Site.

During the period of basalt deposition, tectonic pressure was very slowly deforming the basalt flows into the generally east-west trending ridges that border the Pasco Basin today. After the last major basalt eruption, the Ringold Formation was deposited by the ancestral Columbia River as it meandered back and forth across the relatively flat basalt surface depositing sand and gravel in the central portion of the Pasco Basin. Two major interruptions that occurred when the Columbia River was blocked downstream caused a lake to develop in the Pasco Basin. Relatively thick mud layers accumulated in the lake each time. About 3.4 million years ago, the Columbia River began to erode, rather than deposit, sediments in the Pasco Basin. The uppermost mud layer was eroded from much of the Pasco Basin and a caliche layer, part of the Plio-Pleistocene unit, developed in places on the eroded surface of the Ringold Formation.

The Hanford formation sediments were deposited by catastrophic ice age floods during the past 700,000 years. Fine sands and silts were deposited in slack-water areas at the margins of the basin. However, primarily sand and gravel were deposited on the Hanford Site. In places, these sediments are covered by up to a few meters of recent alluvial or windblown deposits.

More detailed information on the geology of the Pasco Basin can be found in Connelly et al. (1992a and b), DOE (1988), Hartman and Lindsey (1993), Lindberg (1993a and b), Lindsey and Jaeger (1993), and Swanson (1992).

Ground-Water Hydrology

Both confined and unconfined aquifers are present beneath the Hanford Site. An aquifer is a water-saturated geologic unit that has a high permeability, meaning it can transmit significant quantities of water. A confined aquifer is bound above and below by low-permeability materials such as the central parts of basalt flows, clay, or well-cemented sediments. The confined aquifers at the Hanford Site are found primarily within interflows and interbeds of the Columbia River basalts, as well as below the relatively impervious clays and silts of the Ringold Formation. In some areas of the Site, the lower units of the Ringold Formation are only locally confined by discontinuous clay and silt layers above.

Unconfined aquifers, or water-table aquifers, are overlain by unsaturated sediments. In general, the unconfined aquifer at Hanford is located in the Ringold Formation and the Hanford formation. In some areas, the water table (the upper surface of the unconfined aquifer) is below the bottom of the Hanford formation and the unconfined aquifer is entirely within the Ringold Formation. The Hanford formation sands and gravels are unconsolidated and are generally much more permeable than the compacted and silty Ringold Formation gravels. Clay and silt units form low-permeability zones in the Ringold Formation.

The unconfined aquifer forms the uppermost ground-water zone and has been directly impacted by waste-water disposal at the Hanford Site. For this reason, it is the most thoroughly monitored aquifer beneath the Site. The Rattlesnake Ridge Interbed is the uppermost, widespread basalt-confined aquifer within the Pasco Basin and the Hanford Site. This aquifer and other basalt-confined aquifers are generally isolated from the unconfined aquifer by dense rock that forms the interior of the basalt flows. However, interflow between the unconfined aquifer and the basalt-confined aquifer system is known to occur at faults that bring a water-bearing interbed in contact with other sediments or where the overlying basalt has been eroded to reveal an interbed (Graham et al. 1984, Newcomb et al. 1972, Reidel et al. 1992). Additional information on the basalt-confined aquifer system can be found in Spane and Webber (1995) and Spane and Vermeul (1994).

The thickness of saturated sediments above the basalt bedrock is greater than 200 m (656 ft) in some areas of the Hanford Site and thins out along the flanks of the basalt ridges (Figure 4.8.4). Depth from the ground surface to the water table ranges from less than 0.3 m (1 ft) near the Columbia River to more than 106 m (348 ft) in the center of the Site. The unconfined aquifer is bounded below by either the basalt surface or, in places, the relatively impervious clays and silts within the Ringold Formation. The water table defines the upper boundary of the unconfined aquifer. Laterally, the unconfined aquifer is bounded by basalt ridges and by the Yakima and Columbia Rivers. The basalt ridges have a low permeability and act as a barrier to lateral flow of ground water where they rise above the water table (Gephart et al. 1979). The elevation of the water table in meters above mean sea level for the Hanford Site and adjacent portions east and north of the Columbia River is shown in Figure 4.8.5.

The water-table elevation contours shown in Figure 4.8.5 indicate the direction of ground-water flow and the magnitude of the hydraulic gradient in the unconfined aquifer. Ground-water flow is generally perpendicular to the water-table contours from areas of higher elevation or head to areas of lower head. Areas where the contours are closer together are high-gradient areas where the "driving force" for ground-water flow is greater. However, because sediments with low permeabilities inhibit ground-water flow and produce steeper gradients, a high gradient does not necessarily mean high ground-water velocity. The permeability of the Ringold sediments is generally lower than that of the Hanford sediments, so lower transmissivity and steeper gradients are often associated with areas where the water table is below the bottom of the Hanford formation. Figure 4.8.6 shows the generalized distribution of transmissivity as determined from ground-water flow model calibration.

Recharge of water within the unconfined aquifer comes from several sources (Graham et al. 1981). Natural recharge occurs from infiltration of precipitation along the mountain fronts, runoff from intermittent streams such as Cold Creek and Dry Creek on the western margin of the Site, and limited infiltration of precipitation on the Hanford Site. The unconfined aquifer is also recharged by the Yakima River where it flows along the southern boundary of the Hanford Site. The Columbia River is the primary discharge area for the unconfined aquifer. However, the Columbia River also recharges the unconfined aquifer for short periods during high river stage when river water is transferred into the aquifer along the riverbank. Ground water discharges to the surface north of the 200-East Area forming West Lake. West Lake is a small saline water body formed in a closed depression. The size of West Lake fluctuates in response to changes

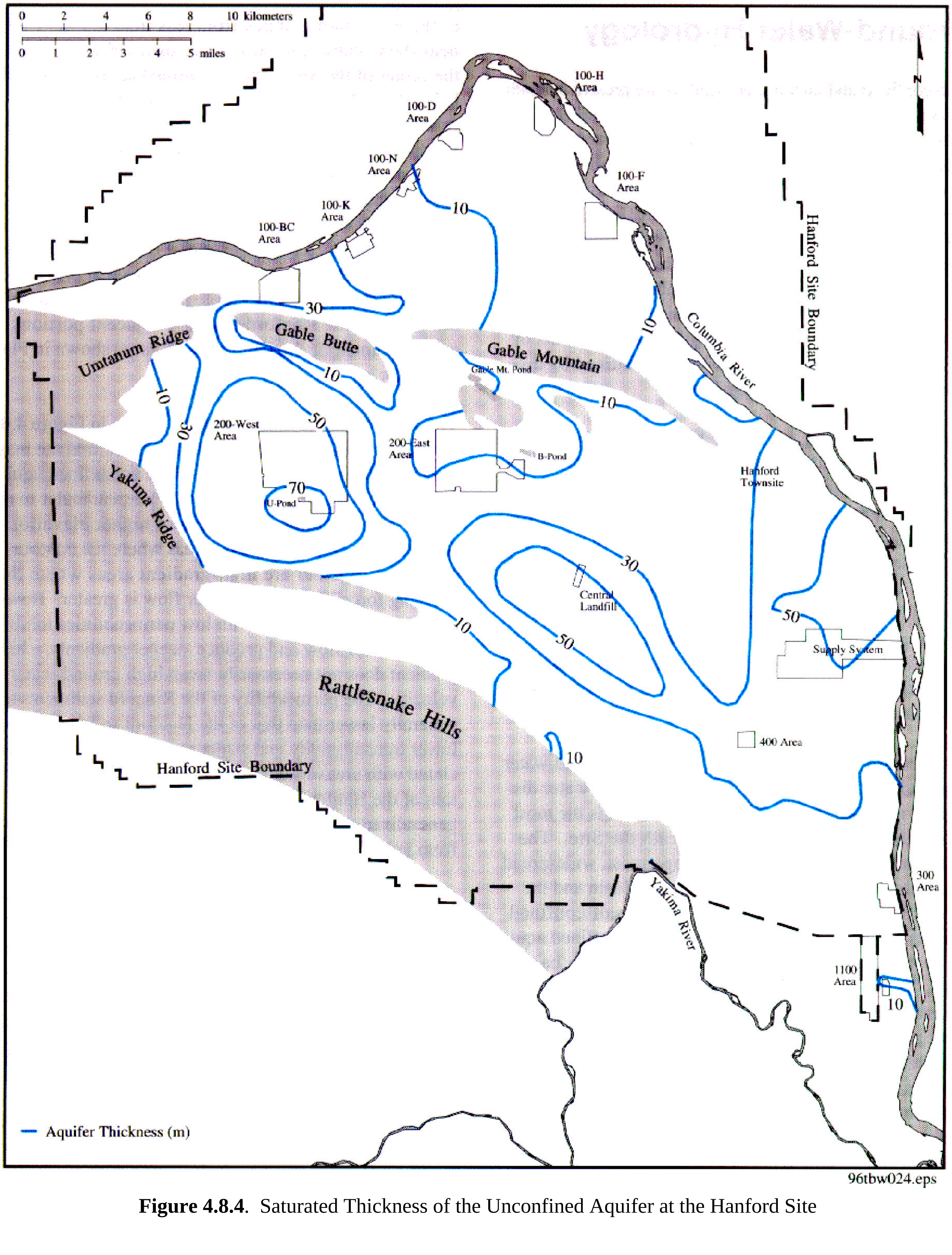

Figure 4.8.4. Saturated Thickness of the Unconfined Aquifer at the Hanford Site

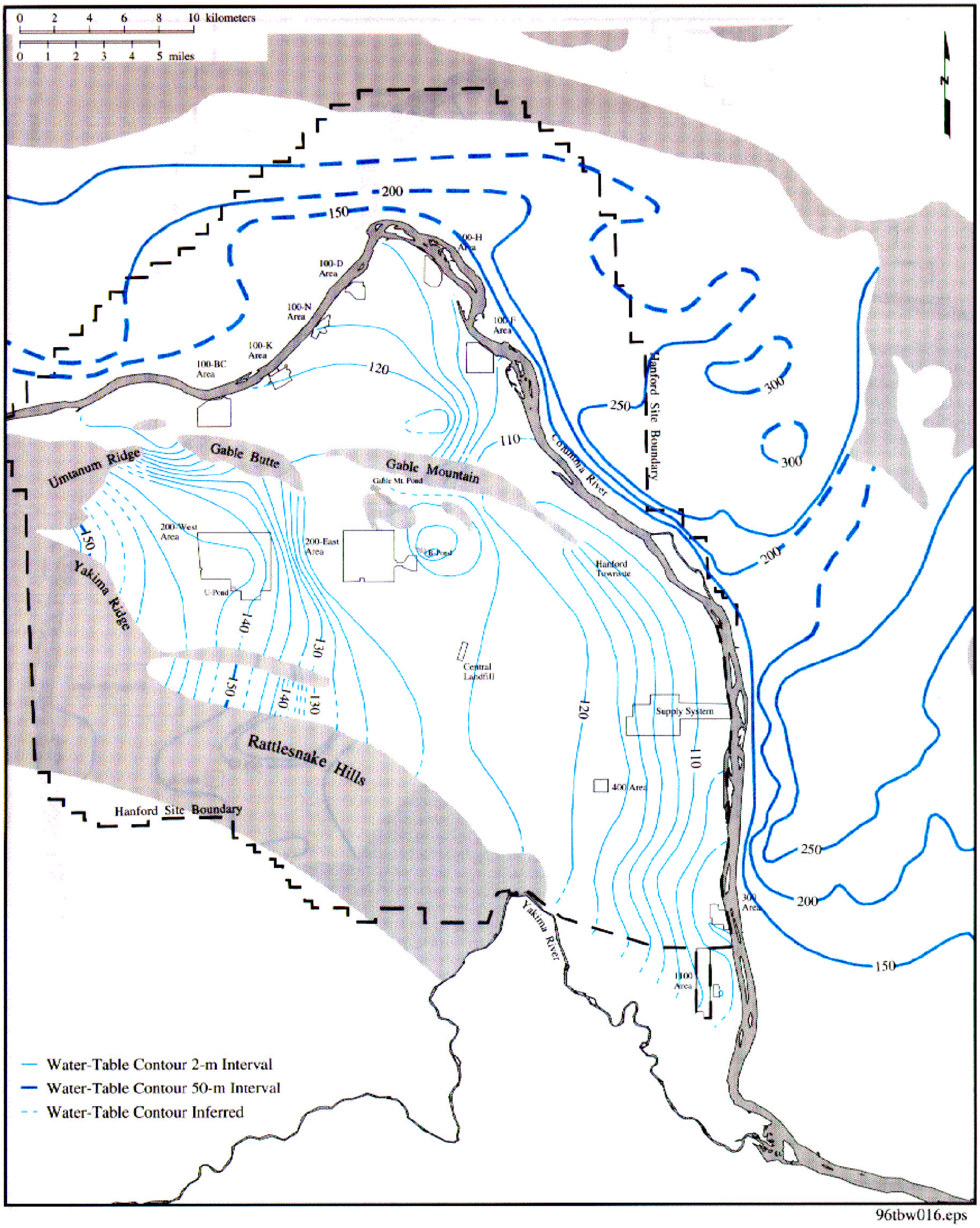

Figure 4.8.5. Water-Table Elevations for the Unconfined Aquifer at Hanford and in Adjacent Areas East and North of the Columbia River, June 1995

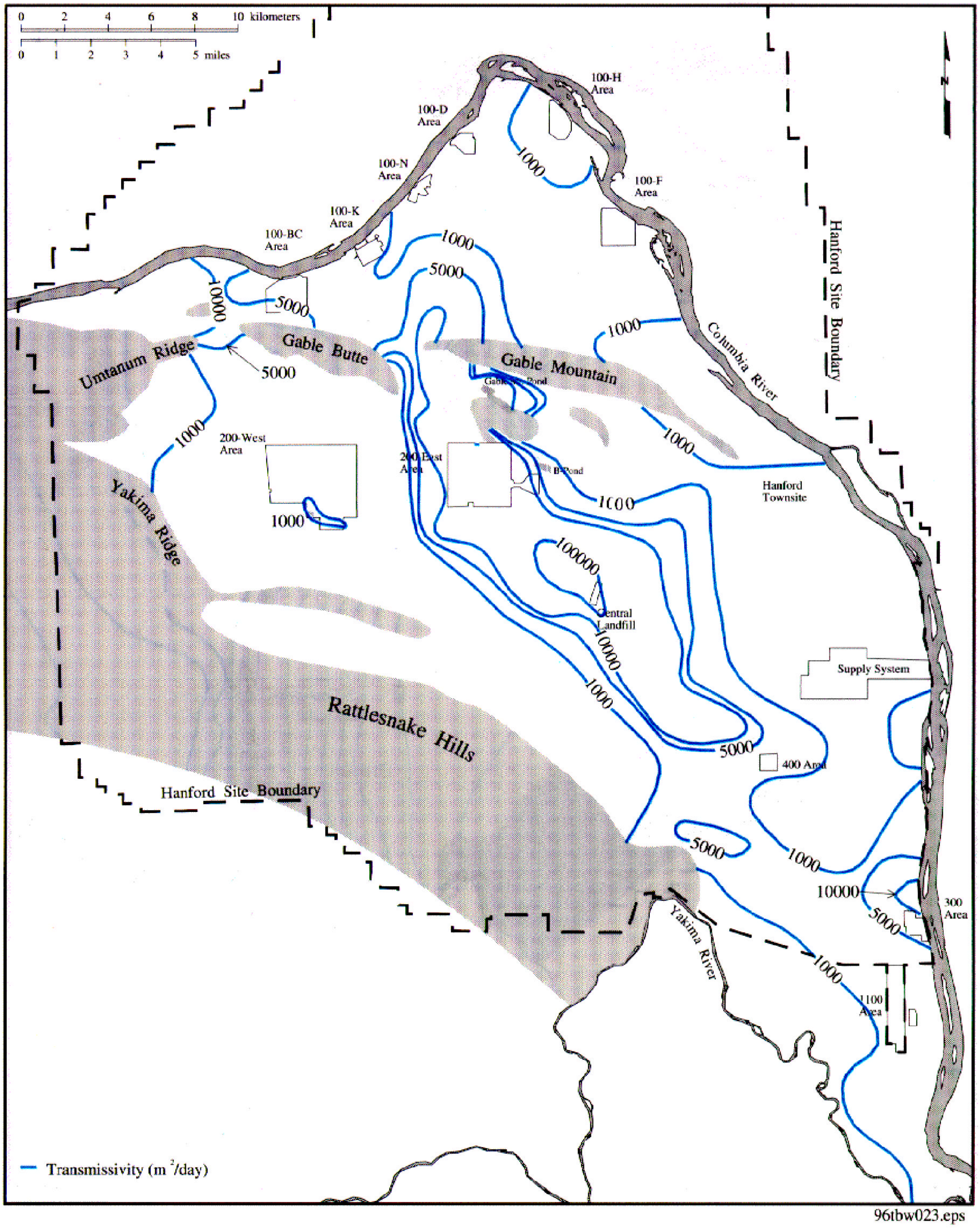

Figure 4.8.6. Distribution of Transmissivity of the Unconfined Aquifer at the Hanford Site

in the water table (Posten et al. 1991). Site discharge has influenced the size of West Lake. Sampling of West Lake is discussed in Section 4.2, “Surface Water and Sediment Surveillance.” Recharge from infiltration of precipitation is highly variable on the Hanford Site and depends on soil texture, vegetation, and climate (Gee et al. 1992, Fayer and Walters 1995). The recharge rate from precipitation ranges from near zero, where fine-grained soils and deep-rooted vegetation are present, to more than 10 cm/yr (4 in./yr) in areas where soils are coarse-textured and bare of vegetation.

Large-scale artificial recharge to the unconfined aquifer occurs from liquid-waste disposal in the operating areas and offsite agricultural irrigation. Discharge of waste water has caused the water table to rise over most of the Hanford Site. Local areas with elevated water tables are called ground-water mounds. Figure 4.8.7 shows the change in water table elevations between 1948 and 1979, when the water table had stabilized over most of the Site. During the past 10 years, water-table elevations have declined in response to a decrease in liquid-waste discharges from Hanford operations. The change in water table elevations from 1979 to 1995 is shown in Figure 4.8.8. Irrigation in the Cold Creek Valley has increased water levels in this area west of the Hanford Site. Recharge from the Cold Creek Valley irrigation enters the Hanford Site as ground-water flow across the western boundary. Recharge from irrigation and canal leakage in agricultural areas across the Columbia River from the Hanford Site has caused larger water table increases than those on the Hanford Site. As indicated in Figure 4.8.5, the water-table elevation to the east of the Columbia River is currently from 50 to 150 m (328 to 492 ft) higher than the water-table elevation on the Hanford Site.

Two major ground-water mounds formed in the 200 Areas in response to waste-water discharges. The first of these mounds was created by disposal at U Pond in the 200-West Area. This mound is slowly dissipating because the pond was decommissioned in 1984. The second major mound was created by discharge to B Pond, east of the 200-East Area. The water-table elevation near B Pond increased to a maximum of about 9 m (29 ft) above pre-operational conditions before 1990 (Newcomer 1990) and has decreased slightly over the last 5 years because of reduced discharge. These mounds have altered the unconfined aquifer’s natural flow pattern, which is generally from the recharge areas in the west to the discharge areas (primarily the Columbia River) in the east and north. Water levels in the unconfined aquifer have continually changed as a result of variations in the volume and location of waste water discharge. Consequently, the movement of ground water and its associated constituents has also changed with time. Ground-water mounding has also occurred in some of the 100 Areas and the 300 Area. Ground-water mounding in these areas is not as great as in the 200 Areas because of lower discharge volumes and high permeability.

In the 100 and 300 Areas, and other locations near the river, ground-water levels are influenced by river stage. Water levels in the Columbia River fluctuate on annual and daily cycles. The river level is controlled by the operation of Priest Rapids Dam upstream of the Hanford Site. As the river stage rises, the increased water pressure is transmitted inland, increasing water levels in wells near the river. Very near the river, water flows from the river into the aquifer when the river stage is high and flows in the opposite direction when the river stage is low. This produces some dilution of contaminants near the river. However, the pressure effects of river stage variation are observed much farther inland (up to 1.6 km [1 mi] in places) than the river water actually travels.

Contaminant Transport

The present distribution of contamination in ground water at the Hanford Site is controlled by the disposal history and the physical and chemical principles of contaminant transport. The conceptual model of contaminant transport describes the processes that control the contaminant movement. Major features of a conceptual model for contamination at the Hanford Site are discussed below.

Most of the ground-water contamination onsite resulted from discharge of waste water from Site processes. Table 4.8.1 lists major contaminants found in each area and the type of operation that generated the contaminants. In the 100 Areas, discharges included reactor cooling water, fuel storage-basin water, filter backwash, and smaller amounts of waste from a variety of other processes. In the 200 Areas, large quantities of contaminated water from fuel processing were discharged. Other contamination sources in the 200 Areas include plutonium purification waste and decontamination waste. In contrast to other major contaminant sources, the plutonium purification process also resulted in the discharge of large amounts of chemicals in a liquid organic chemical form. In particular, carbon tetrachloride was discharged in the 200-West Area in a liquid organic chemical form. This liquid, once in contact with ground water, slowly dissolves

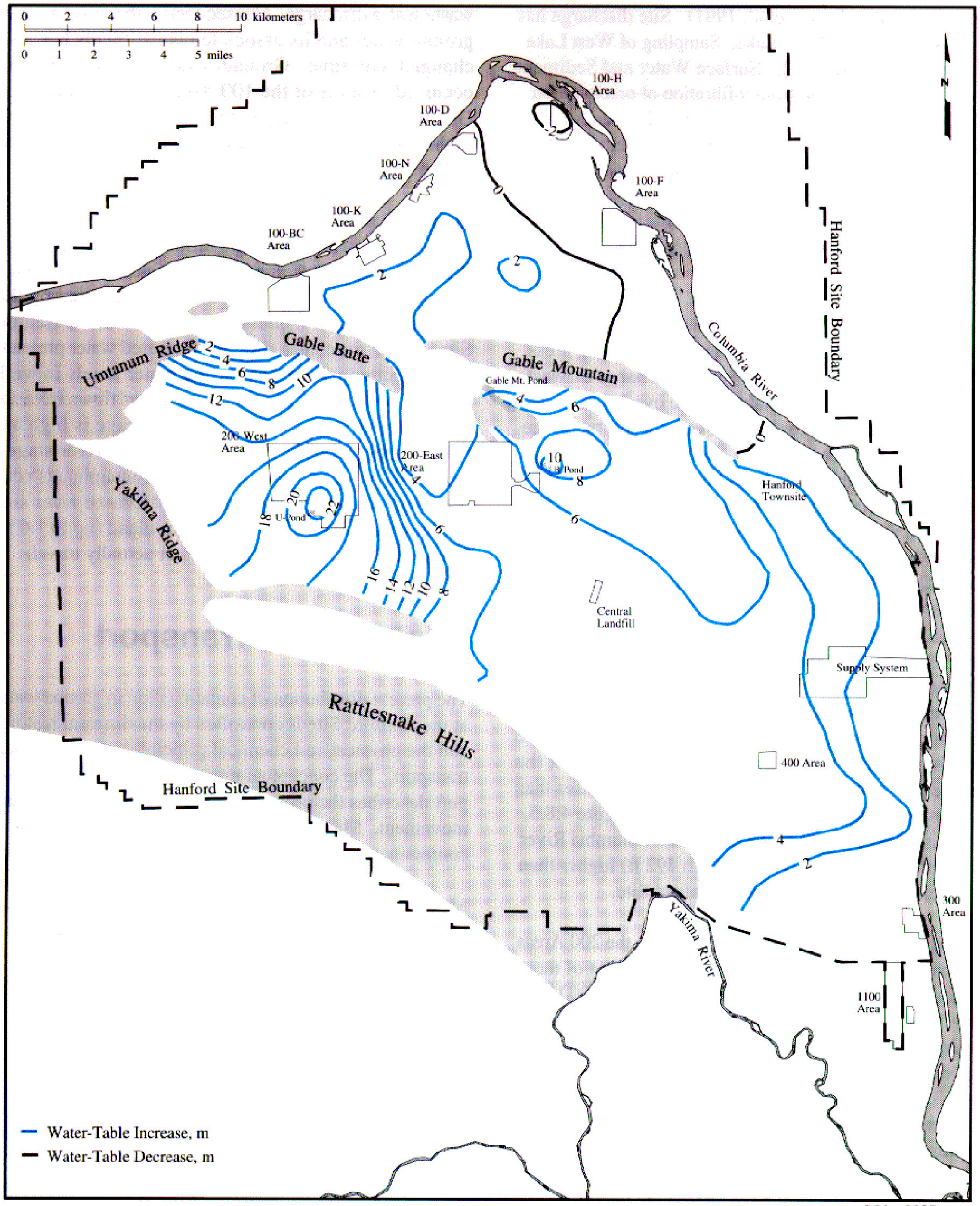

Figure 4.8.7. Change in Water-Table Elevations Between 1944 and 1979

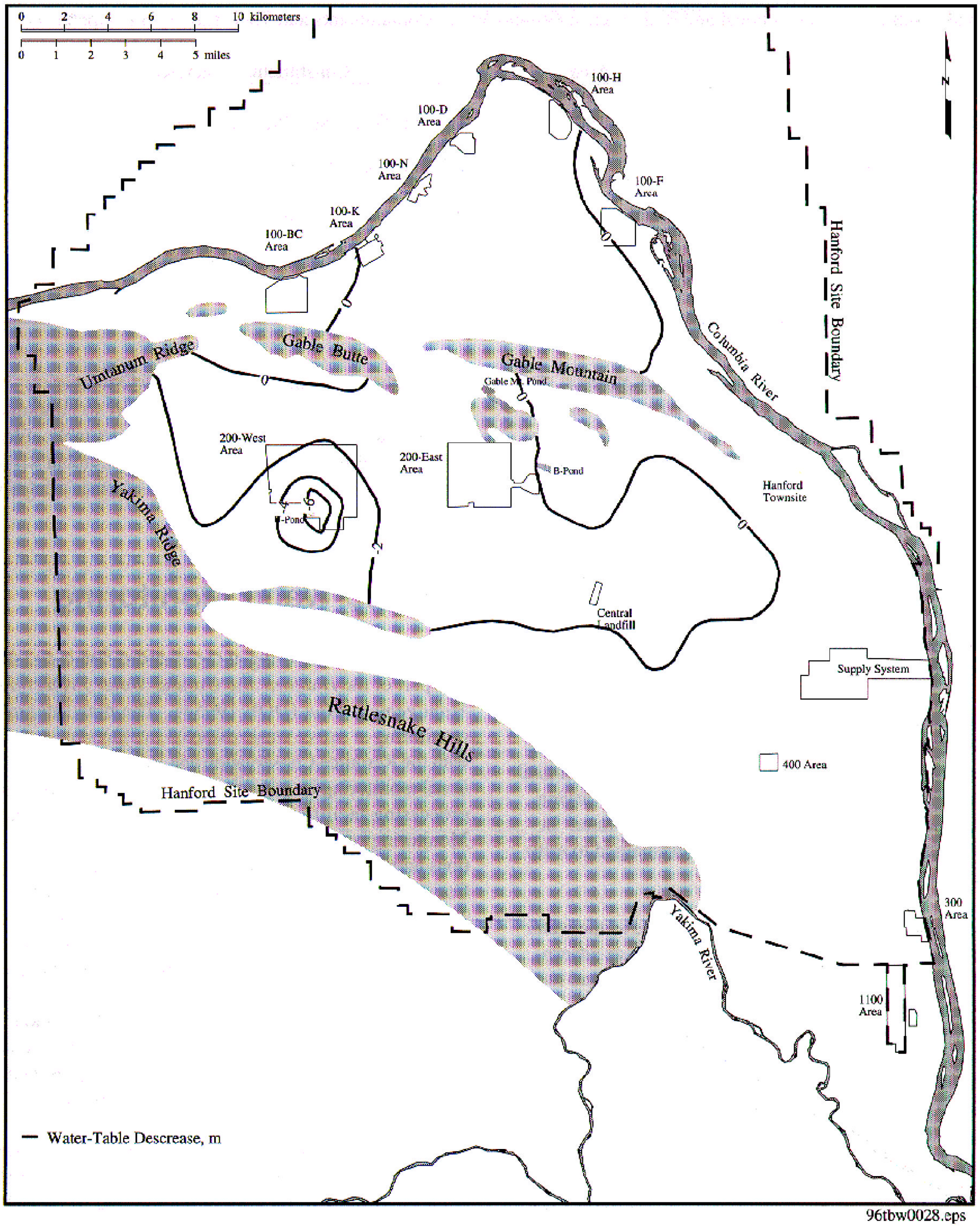

Figure 4.8.8. Change in Water-Table Elevations Between 1979 and 1995